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FROM THE TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA.

THIRD SERIES—1909-1910

VOLUME III SECTION IV

The Semi-Centennial of the Origin of Species.—The Presidential Address in Section IV.

By

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OTTAWA

PRINTED FOR THE ROYAL SOCIETY OF CANADA.

1910

XII.—*The Semi-Centennial of the Origin of Species.—The Presidential Address in Section IV.*

By A. B. MACALLUM, Ph.D., Sc.D., LL.D., F.R.S.

(Read May 25, 1909.)

This year is to all who are concerned with the things of the mind one which makes us pause to take stock of our acquirements as well as of our mental impedimenta, for it is the fiftieth anniversary of the publication of "The Origin of Species." To the man on the street that does not count for much but we who recognize at what cost ideas are won will at once concede that it is our duty to scrutinize closely what we have gained from it, to sift out what is only temporary, and thereby prepare to take a distant view of the path along which we are yet to advance.

That it is serviceable to take stock of our ideas will be denied by few. It has been well said by Duclaux that Science advances because it is never sure of anything, and the best way to stimulate that progress is to revise constantly one's standards of intellectual values. Such revision comes more readily, as on the present occasion, when after a sweep of years the subject itself has lost some of the original associations which made at the time its fate appear ambiguous and when in a clearer atmosphere the distortions which characterized the original setting of the subject have given way to clear-cut, unchanging outlines and just propositions. Further, to appreciate the past as well as the present form of a great idea helps us to adjust sanely the ideas which are now in birth or development among us, and we are thus enabled to view them as if we were in advance of our time.

There is another effect which follows from taking stock of what we have won from our intellectual past. In all attempts to appraise the true value of our intellectual heritage we do justice to and make worthy those who in less auspicious times valiantly strove for truth. It is a custom of ancient origin in the Chinese Empire to grant posthumous honours to those who have done great service to the State, and it is without doubt founded on the worship of ancestors. To the western mind it appears a curious, bizarre custom, and to us to postulate a mental attitude that is uncritical and approximates that usual in the childhood of a race; but who amongst us of the West does not pride himself on his ancestry if, in his line of descent, there are one or more who in their day stood out from "the dim common populations" and achieved distinction the record of which is known and cherished. Is he then less worthy for whom a later generation, not a King or Emperor, has in gratitude decreed a position which ranks him with the illustrious dead?

There is another reason why we should on occasions like the present revise our views and acknowledge our debt to those who have laboured in the cause of truth. They have been of the class that are always in advance of their day. They are in the best sense of the word supermen, that is, representatives of the race as it is yet to be. The intellectual portion of mankind, therefore, in honouring them proclaims the solidarity throughout the ages of the *aristoi* of the race. What this means in our intellectual development may best be conveyed in the words of a seventeenth century French author: "Il nous faut, si nous espérons de parvenir à quelque gloire, hanter avec les morts."

These preliminary observations bear on the ceremonies that are being arranged to celebrate the semi-centennial of the publication of the "Origin of Species," and they are advanced now because of the view that I hold that this Society should, at least on occasions like the present, bring its tribute to the memory of the author of that epoch-making work. The University of Cambridge, Darwin's Alma Mater, has issued invitations to the Universities and learned Societies and Academies of the world to send representatives to take part with it next month in its great assembly to do honour to him and his work. This Society has responded and has nominated one of its members, Professor W. H. Ellis, as its representative at that function. We should not let the occasion pass with that and it is, therefore, but fitting that in this Section I should now, as President of it, offer a direct tribute to the great philosophical naturalist for his service to the highest intellectual interests of mankind.

In attempting this duty I shall not, however, strive to give a comprehensive survey of his work. That duty I must leave to be performed by others and in a manner that measures up to so colossal an achievement. I shall content myself with discussing some aspects of his great concept, and with an attempt at an appraisement of what has been the effect on our intellectual outlook.

It has been often said that the doctrine of Evolution did not originate with Darwin. That is true for Lamarck advanced it in his "Philosophie Zoologique" published in 1809. It was postulated by Wolff in 1759 in his "Theoria Generationis." It was "back of the mind" in Oken's theory of the segmental character of the skull, a theory which was also independently advanced by Goethe. This accounts for many passages in the literature of the earlier half of the nineteenth century which are now interpreted as postulating a belief in evolution in Nature. Several such passages may be found in "In Memoriam" published in 1850 but composed some years earlier. The Lamarckian hypothesis found a more concrete expression in a speculative work of anonymous authorship

the "Vestiges of Creation," which appeared in 1843 and which at once attracted attention and criticism. The doctrine began to appear in a more or less inchoate form in the scientific contributions. It was dimly foreshadowed in Huxley's Medusa paper published in 1849, and it was as dimly conceived in Lyell's "Principles of Geology," a copy of which was Darwin's companion on the voyage of the Beagle. It was, further, a time when men were turning away from the discussions of empty questions to think of what lay under the surface of things. The period which produced the Bridgewater Treatises and the Oxford Movement had representatives of a widely different line of thought who cast about for solutions of the problems of the world about them. In some cases the two lines of thought were combined, as for example in Faraday and Gosse. This alone shows that the time was ripening for a great event, and the fact that the maturation took such a long time, and yet was of such an inevitable character, indicates as clearly that the doctrine of evolution is of psychological as well as of biological application.

It may be of interest to consider what would have been the history of thought during the last fifty years had Darwin's energies and powers of scientific analysis been directed along some other line or lines. In that case the question would arise; Would the present form of the theory of evolution even in its main outlines now obtain? To this anyone who is conversant with the biological sciences would answer at once in the negative. Though the concept of evolution, dimly conceived, was "in the air" long before the "Origin of Species" appeared, it was but slowly pervading men's minds, and without the contribution of Darwin it would even now be but a formless idea and a theory. The biologists of the last half of the nineteenth century would have accumulated facts of the greatest value as bearing on the concept of evolution. They would have ascertained, as they did, that sexual fertilization involving curious cellular processes is the same in the vegetable kingdom as in the animal. They would further have established, as has been done, that cell division with its intricate phenomena of karyokinesis is in its fundamental characters the same in the two kingdoms. They would also have gathered evidence to show that the characters of a species except in certain cases, numerous enough but still limited, are not fixed, unchanging. Indeed they would have discovered thousands of facts whose significance is not now dwelt on simply because they now fall in their place under the great generalization of Darwin, but which in the absence of such an explanation would unmistakably point to some great evolutionary process. It may well be doubted, however, whether the resulting generalization would have been the theory of evolution as Darwin formulated it and as it obtains to-day. With the accumulation of a countless number of facts

there would have been the greater difficulty in arriving at a generally accepted explanation of them all. There would have been endless discussion, polemics and critiques, and the intellectual force of the biological division of the scientific world would have been largely wasted in such exercises. Accordingly the Time Spirit would not have advanced, and consequently religious and philosophical thought would not now be very different from what it was fifty years ago; but above all the application of the theory of evolution to the physical side of the Universe, one of the greatest achievements and of supreme significance to the thought of our day, would not have been made.

It is Darwin's great and never-to-be-forgotten merit that he attacked the central point of the problem and concentrated all the intellectual force of the age on it. Instead of leaving the theory of evolution to emerge slowly from the scientific and philosophical discussions of his generation, "The Origin of Species" made it at once the cardinal issue in the world of thought. Because of the setting in which the doctrine was placed it was at once accepted by the great majority of biologists and naturalists. This was due to the vast mass of facts which he had patiently collected for twenty-one years and also to the long consideration which he had given the theory from 1843 on. In consequence when the book appeared the theory was elaborated in all its details and to such a degree of completeness as to parallel the birth of Minerva, armed with shield and spear, from the brain of Jupiter. The immediate effect was division in the biological world and almost unanimous opposition from the theologians, metaphysicians and moral philosophers. The opposition of these latter would not have been aroused to the same extent had not the supporters of the theory raised the question of applying the theory in explanation of the origin of moral and ethical ideas. This intensified the keenness of the discussion and precipitated into the struggle all the representatives of the older schools of thought. In the twenty-one years following the publication of the "Origin of Species" there was no topic as much discussed as Darwinism, and there has never been a subject of philosophical and scientific import which has excited more bitter and unfair opposition and criticism.

Perhaps the bitter opposition was the best treatment that the new idea could have experienced if it were ultimately to prove acceptable and make headway. The keenest criticism could only at once have revealed how strong or how weak it might be and of course its fate would sooner be decided. The discussion, as it went on, served to clear ideas, it made the concept diffuse through the minds of the intellectuals throughout the world whose verdict finally silenced opposition.

The heat and acrimony of the conflict are now but a memory, and we are of a generation which takes evolution more or less for granted. In consequence of an uncritical reception of the doctrine, almost as if it were part of the air we breathe, there are few of our representative thinkers who can give as good reason for the faith that is in them as was the case with many of the former generation. It is, as Huxley said in 1880, the customary fate of new truths to begin as heresies and end as superstitions; and he went on to add, that as matters then stood it was hardly rash to anticipate that, in another twenty years, the new generation, educated under the influences of that day, would be in danger of accepting the main doctrines of the "Origin of Species" with as little reflection and, it might be, with as little justification as so many of his contemporaries twenty years earlier rejected them.

What Huxley anticipated has come about. The philosopher, the historian, the journalist, the chemist, the physicist, the geologist and even the theologian, accepts without as much as a superficial critical examination the theory of evolution. Only amongst two classes is there any tendency to question the validity of the theory. One of these classes includes those whose religious creed is utterly opposed to evolution in any form, and who would only accept the theory when it came to them as a dogma to replace a discarded part of their creed. The other class comprehends not only biologists but also all those who have intellectual curiosity and exercise it in this line. To this latter class the doctrine is ever on its trial, and it is well for the development of human thought that it is so.

To this class the theory in the last few years has seemed to lose ground. Mendelism, De Vries' mutation theory and Weismann's theory of the continuity of the germ plasma all appeared to undermine the cardinal points in the theory, and in consequence one hears and reads now and then that the theory is exploded.

Nothing could be farther from the truth. What effect Mendelism may have on the doctrine is yet to be known but so far it appears to leave it where it was. The mutation theory is to the effect that rapid and very important variations may occur, and thus the production of one species from another may arise by the "saltation" method, instead of developing by the slow method which Darwin postulated and which the mass of evidence seems to indicate. That mutation may occur in a few forms seems to be conceded, but it is exceedingly doubtful if it is a general factor in species-making.

In only one respect have Darwin's views apparently failed to find acceptance in recent years. This was in the theory of heredity known as Pangenesis. This theory was not propounded in the "Origin of Spe-

eies." It was first given in the "Variation of Animals and Plants under Domestication" which appeared in 1868. It at once met criticism on all sides even from some of those who were staunch supporters of Darwin's views on Evolution generally. It did indeed win favour for a time, but it is now regarded as merely an interesting speculation which has had its day.

The reason for this is not far to seek. The theory was advanced to explain what was generally accepted as a fact. It was commonly believed that anatomical or structural characters acquired by an animal during its own life through injury, mutilation or extraordinary use or disuse of any organ or structure, could be transmitted to its own immediate offspring. It was not that any one postulated such a result in every case, for the ordinary individual holding such a view was prepared to admit that an animal with cropped ears would not necessarily in every case produce offspring with ears different in shape from that normal in the species, and that, further, a dog or a cat deprived through an operation of its tail did not necessarily produce tailless pups or kittens. It was, however, held that when, after a parent form had undergone a structural alteration in one of its organs through an injury, one or more of its offspring manifested a similar alteration, the result was due to inheritance. Why such alterations in the parent form were not always followed by similar changes in the offspring was not explained, nor was an attempt made to do so. All that was in concern was the occasional transmission of such characters.

This belief appeared to be supported by the results of observations on plants and animals in the state of domestication. It was recognized that both plants and animals when in an artificial environment manifest an extraordinary variability, and that unusual characters appearing under these conditions could by artificial selection in breeding be transmitted to the offspring. Evidence of this was found in garden flowers, in pigeons and other domestic animals, some of which have developed in this way such differences in character as to make them appear as if they represented new species. Such unusual characters were supposed to be due to the direct action of the food or of the environment or of both the food and the environment.

The effect of use or disuse of an organ, or of the functional stimulation of parts in an animal form, in influencing the character of its offspring was of cardinal importance in the theory of Lamarck advanced exactly half a century before the "Origin of Species" appeared. Darwin also in the latter work discussed the results of use and disuse of parts and showed, as has been done again and again since quite clearly, that we must recognize that use and disuse are in the history of a species

very important determinants of its structure. It is only necessary to bring forward illustrations of the effects of disuse from animals which inhabit caves. These are all either partially or totally blind, for the power of vision is useless in the darkness of cavern life. The eyes are either reduced in structure, partially atrophied or undeveloped. An example of the last condition is found in some of the crabs in which the "footstalk for the eye remains, though the eye is gone,—the stand for the telescope is there, though the telescope with its glasses has been lost" (Darwin). For the effects of use Darwin referred to the insects of Madeira which are not ground-feeders, and which as flower-feeders have to battle with the wind so as not to be blown out to sea. In these the wings are fully developed and even enlarged, while in the ground-feeding insects the wings are atrophied because normal wings have been of no service and were, therefore, not used.

Such results were supposed by Lamarck and his school to be explained by the transmission of acquired characters, to use Weismann's expression, but Darwin nowhere expresses an unqualified adhesion to this view. Indeed in a letter[1] to A. de Candolle he wrote:—"I must own that I have great difficulty in believing that any temporary condition of the parents can affect the offspring. If it last long enough to affect the health or structure of the parents I can quite believe the offspring would be modified." It is to be noted that a rigid examination of all the cases which seem to prove the direct transmission of acquired characters had not been made before Weismann undertook to examine the record in 1881 and consequently it was incumbent upon Darwin to advance an explanation of how this transmission occurred. Heredity was a known force, and, as it was supposed to be exemplified in the transmission of acquired peculiarities, the result was the production of the theory of Pangenesis.

This theory briefly stated postulated that every cell of the body gives off small particles of a character peculiar to and representative of each of such cells, and that these circulating in the body fluids, blood and lymph, finally reach and penetrate the sexual cells, the ova and spermatozoa. The latter thus contain representative particles from every cell of the body and thus each ovum or spermatic element is, as it were, a microcosm of the parent body. These representative particles, or, as Darwin called them, "gemmules" act in such a way in the ovum, after fertilization takes place, as to bring about in the offspring thus arising a complete reproduction of all the characters of both parents. The

[1] More letters of Charles Darwin, 1903, Vol. I, p. 348.

gemmules derived from the cells of an atrophied organ in a parent would thus account for the appearance of atrophy of the organ in the offspring while those from an organ whose size has been enhanced by use determine the special development of the organ in the next generation.

As already stated this theory met at the outset trenchant criticism. It was pointed out that a single ovum of an adult animal, a vertebrate, for example, would have to contain many times more gemmules than its cubic capacity provided for unless they were of exceedingly minute size, that is no larger than simple molecules, in which case they could hardly be representative of the cells giving origin to them. There was also the difficulty of understanding how the germinal cells received only the same number of gemmules from each individual part of the body, for the gemmules of the tissues and cells adjacent to the growing germinal cells would reach the latter in greater numbers than those from more distant parts. To explain this one would have to invoke the idea of a special affinity on the part of the germinal cells for gemmules from the more remote structures of a degree in proportion to the remoteness, or to postulate the existence of some unknown directive force, not only guiding the course of the gemmules, but arranging them in the germinal cells in such an order that alterations in the organs of either or both of the parents would be reproduced in the offspring. To postulate such an affinity on the part of the germinal cells or such an unknown force in an explanation of heredity merely substitutes one difficulty for another.

The most damaging criticism, however, came fifteen years after the promulgation of the theory. In 1883 Weismann denied in toto the validity of the evidence on which the belief in the inheritance of acquired characters was based. He was not the first to do so for Kant ridiculed the belief as baseless, and His about twelve years before Weismann also disputed the facts, but Weismann was the first to direct attention to the cardinal point in the discussion, and it is his great merit that he has placed the subject in a wholly new light. His analysis of the facts which have been adduced in support of the inheritance of mutilations and other artificially produced structural alterations showed quite unmistakably that very many of these are not to be regarded as trustworthy and that others may be explained as not due to inheritance of such characters in any respect. In consequence of his efforts and teaching a school of biologists has developed during the last twenty-five years which regards all the evidence advanced in support of the belief in the inheritance of acquired characters as absolutely baseless.

It is this attitude of mind amongst biologists generally that doomed the theory of Pangenesis. If acquired characters are not transmitted gemmules of the character demanded by the theory are not needed and

do not obtain. There followed from this the conclusion that the germinal cells are unaltered during the life of the individual organism.

This conclusion is embodied in the theory formulated by Weismann known as the Continuity of the Germ-Plasm. According to this the substance of the germinal cells which transmits parental characters is not affected during the life of the parent and this substance which Weismann called the germ-plasm is conveyed unchanged from one generation to another. This germ-plasm obtains in every ovum and spermatic element and when the former is fertilized it receives the germ-plasm of the male element. In the development which follows a portion of the blended germ-plasm derived thus from the two parents remains unchanged and is stored up in the germ cells of the embryo. When the latter becomes adult the germ-plasm thus separated and husbanded is conveyed to its offspring. In this way, according to Weismann, the fertilized ovum of the tenth generation would contain $\frac{1}{1024}$ of the germ-plasm of the first but this he holds as sufficient to account for the appearance of remote ancestral characters.

The germ-plasm so continued from generation to generation is the dominant, the all-determining factor in heredity. It "not only contains the whole of the quantitative and qualitative characters of the species, but also all individual variations as far as these are hereditary." It is, accordingly, "a substance of extreme stability, for it absorbs nourishment and grows enormously without the least change in its molecular structure." It is not a simple substance but it "possesses a very complex constitution, for it consists of a number of ancestral germ-plasms represented in very different proportions." "Certain ancestral germ-plasms will meet and together produce a double effect; other opposed germ-plasms will neutralize each other; and between these two extremes all intermediate conditions will occur." [1]

Such was the germ-plasm as Weismann first defined it. It was absolutely stable and perpetually immutable. In later years he modified his conception of its characters and he now attributes to it the capacity to change its qualities, which capacity is influenced by marked fluctuations in the nutritive stream directed towards the germinal cells. These fluctuations are in their turn due to changes in the environment, as when, for instance, the species is brought into new conditions of existence, for then the nutritive currents within the germ-plasm alter and in consequence its qualitative composition varies. These variations may go on indefinitely, and indeed Weismann assumes "that the phyletic evolution

[1] The quotations are from Weismann's "Essays on Heredity," English Translation, The Clarendon Press, Oxford, 1889.

of the organic world is only conceivable on the assumption of continual variation of the germ-plasm, that it actually depends upon this even if these variations come about with exceeding slowness, and are thus in a certain sense difficult."

In the main the former conception of the germ-plasm still holds. It is not altered or affected during the life of the individual by alterations in structure of the body, by mutilations, or by results of use or disuse. Only by nutritive fluctuations may it be affected, and then in the vast majority of forms to such a degree as to produce results observable only when these are cumulative through a large number of generations. Even when thus altered the germ cells preserve some of the ancestral germ-plasm, and thus remote atavistic qualities may be reproduced. The greatest variation, however, comes from the mingling of the germ-plasms of the two parents, which occurs in fertilization. This is the perpetual source of the appearance of new characters in a species, the sexual process insuring thus a diffusion of such qualities amongst the members of a species; but such diffusion is never completed and variation, therefore, may proceed to an infinite extent.

I have thus dealt at some length with the theory of the Continuity of the Germ-Plasm because it is the one which has replaced Darwin's Pangenesis, and because also an understanding of its main points leads to a consideration of a number of facts which suggest quite another explanation of the facts of heredity.

It is now generally accepted that the germ-plasm is the chromatin in the reduced nucleus of the ovum and in the spermatic cell. Indeed Weismann's *ids* are but the chromosomes left after the reduction of the chromatin through the formation of the polar bodies.

It is, therefore, of interest to us to inquire into the history of this chromatin and, for that matter of all chromatin to see if it is such a persistent substance as Weismann claims it to be, and, if persistent, to ascertain why it has this property.

The current view as to the function of the nucleus is that it is the directive organ in the nutrition of the cell. If it does not elaborate everything in the cell it is an active agent in all the metabolic processes of the cell. It is never conceived of as a passive structure. Gruber's experiments on artificial division of the bodies of Infusoria showed that, while fragments of the cell which contained a portion of the nucleus of the original structure grew and replaced the parts lost by division, those fragments which contained no remnant of the nucleus invariably perished. Further, it is undeniably true that, in the fertilization of the ovum, the substance transferred to the latter is chiefly if not wholly the chromatin of the spermatic element, and this unites with the "reduced"

chromatin in the female pronucleus to form the first nucleus of the new organism. All this postulates that the chromatin is the bearer of the qualities of heredity, in other words, that it is the material which directs all the course of development of the offspring. Further, it is commonly assumed that the chromatin in the nucleus has been formed there out of simpler material reaching it from the surrounding cytoplasm, or ultimately from the circulatory fluid in a metazoon or metaphytan form.

If this latter assumption is well founded then Weismann's germplasm may exist, indeed, must exist, for if the nucleus manufactures its own chromatin the processes involved must rarely if ever vary, and consequently the product, the heredity-bearing material, must be persistent in its composition.

The cardinal point then is does the nucleus form its own chromatin or is it derived from without?

On this point we have little evidence, but such as it is it is of value. Iwanoff [1] has shown in the case of the yeast organism that the cytoplasm contains a ferment which converts phosphoric acid and sugar into a compound in which the acid is masked as it is nucleic acid. This compound is, in all probability, the skeleton component of chromatin. Popoff [2] has recently demonstrated that in Protozoa, when a portion of the cytoplasm is cut away, the chromatin of the nucleus is less readily replenished than in the intact cell.

There are also the observations which I made seventeen years ago on larval Amblystoma. In these as in all the lower vertebrates the vitellin of the yolk spherules contains iron and phosphorus and is the source of the iron and phosphorus of the chromatin. Now in the developing larva the vitellin dissolves in the cells, and some of it at least diffuses from them into the blood plasma. The latter at a certain stage of development gives in sections of the embryo distinct evidence of the presence of a "masked" iron chromatin-like compound which takes the staining dyes readily. At a later stage this diminishes and almost disappears from the blood plasma. The embryonic red cells, before this diminution takes place, manifest an extraordinary activity in division, so much so that each for a time seems to have no resting phase. This, I have explained is due to the richness of the plasma in a chromatin-like material which diffuses into, or is absorbed by, the embryonic red cells, and thus their chromatin is so abundant as to permit many divisions immediately following each other.

The evidence then as far as it goes seems to indicate that chromatin is not wholly formed in the nucleus in which it is found. If it is derived

[1] Zeit für Physiol. Chem., Vol. 50, p. 281, 1907.

[2] Arch. für Zellforschung, Vol. I, p. 245, 1908.

from without then it may be elaborated by many cells or rather by the ferments of many cells. That postulates a circulation of chromatins, or iron-holding nucleoproteins, with the plasma and lymph in the animal body and with the tissue juices in the vegetable organism.

The iron-holding nucleo-proteins from the hepatic nuclei are different from those obtained from the pancreas, and the latter again are different from those of the nuclei of the renal cells. The iron-holding nucleo-proteins of ova must be different from those of somatic cells as otherwise the latter ought to become germ-cells and through fertilization to reproduce the organism.

If these iron-holding nucleo-proteins circulate in the body fluids and in the juices of vegetable organisms, how may it possibly happen that only one kind reaches the nuclei of the germ cells, another the hepatic cell nuclei, a third the pancreatic cell nuclei and so on? The answer that I would give is that the nuclear membrane in each case determines what iron-holding nucleo-protein reaches the interior of the nucleus, and as the nuclear membrane in the different species of cells varies in its physical and, perhaps also, chemical qualities, the chromatin reaching the interior of the nuclei in one type of cells, for example, the germ-cells, is on the whole uniform in composition, but there may be variations in the character of the membrane and consequently the chromatin in the nuclei of the germ-cells may be so different as to give rise in the offspring to modifications of structure of form varying from the simple "sport" to the monstrosity.

It is in this way easy to account for the persistence of characters in a species through a long series of generations and to explain variation. It is possible on this basis to understand the development of the cancer-cell, the origin of a second lens in the Amphibian eye after the removal of the first, the power of cuttings to develop into complete adult plant forms, and to comprehend natural parthenogenesis. We are in a position also to understand why a liver cell gives ordinarily rise only to a liver cell, and a pancreatic cell only to another of the same kind. In a unicellular organism the cytoplasm elaborates one kind of iron-holding nucleo-protein which is stored up in the nucleus, and thus there is a stability of character in these forms, that does not obtain in the Metazoa and Metaphyta.

On this basis we do not need to postulate some mysterious force keeping the germ-plasm continuous or persistent in character. The theory here advanced enables us to understand how variations may arise. It explains how conditions of nutrition may affect the offspring. It does not require us to believe that use or disuse of an organ in a parent may

affect that part in the offspring except in so far as use or disuse may affect the nutrition of the whole body.

That the nuclear membrane has extraordinary selective powers, as regards the substances it permits to diffuse throught it, may be gathered from a few facts. Never, except in pathological tissues, does the nucleus contain fats, carbohydrates, or salts, even when the cytoplasm is charged with these. Further the cytoplasm abounds in proteins but these, if they occur at all, are only in traces in the nuclear cavity. The membrane is the barrier to their entrance. It, however, permits iron-holding nucleo-proteins to diffuse through it. This is seen in the pancreatic cells whose nuclei give origin to an iron-holding nucleo-protein, which I denominated prozymogen, found in the cytoplasm. Further the Nissl granule material in the cytoplasm of the nerve cell of adult vertebrates reaches the cytoplasm by diffusion from the nucleus.

The nucleus, on this conception of its functions, owed its origin to the fact that some intracellular organ was required to receive the heredity-bearing substance and protect it from change chemical and physical.

Before a nucleus arose heredity must have been a very uncertain factor for what then corresponded to chromatin must have been subjected to the action of everything that invaded the cytoplasm from without and especially when the salts of the Archean Ocean increased in concentration. Indeed it was probably the latter that constituted the chief factor in the evolution of the nucleus. There are still, it is true, organisms which are without a nucleus; the Blue-green Algæ, Bacteria and Yeasts. These have external membranes which in a measure protect them from the action of the salts of their environment, and that is, perhaps, the reason why they only have survived from a time when all organisms were non-nucleated.

The nuclei then are the receptacles for all the iron-holding nucleo-proteins formed in the cells of the organism. What kind of such compounds is stored up in a nucleus depends on the physical and chemical properties of its membrane. In the nuclei of the germ-cells a nuclear membrane of a certain quality is present. In the somatic nuclei membranes of other qualities must obtain. To the germ-cells must, on this basis, go one kind of chromatin not absolutely and always the same. Slight alterations in its composition may not prevent it reaching the nuclei of the germ-cells and may thus provide for variation. The somatic cells under certain conditions of environment and of nutrition may constantly prepare such slightly altered chromatin, and thus a regular tendency to variation may obtain. In this way also use and disuse of an organ in an animal can, after a time, influence its offspring.

If we substitute for Darwin's gemmules the molecules of iron-holding nucleo-protein formed in the somatic cells we have a new and tenable modification of his Theory of Pangenesis. This modification does not depend for its value on the inheritance of acquired characters.

Interpreted in this way Pangenesis as a theory of heredity is more in accord with the facts of heredity and of biochemistry and physiology than any other that has been as yet advanced. Accordingly the one of Darwin's cherished views which has hitherto failed to find acceptance is, after all, in my opinion, a demonstration of keen and far-reaching vision on his part.